Understanding the Relationships Between Stakeholder Success and Construction Project Characteristics and Technology Use

by

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Abstract

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Achieving the successful delivery of a project is the goal of every project management team. Because of the multiplicity of personnel involved, a key element of construction project success is stakeholder success. In the final analysis, if a project is to be perceived as successful, then its stakeholders must be satisfied. The cost and schedule performance metrics associated with project success are typically not equally important to all stakeholders and are not adequate measures of stakeholder success. This thesis analyzes survey results by comparing stakeholder success with varying project characteristics and technology usage levels.

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Chapter 1: Introduction

1.1 Background and Motive

The broad focus of construction project management is to successfully deliver a product, in this case a capital facility, to a client. The widely accepted definition of a successful project is one that is executed "on time and on budget" and for some, "conformance to requirements". However the literature is full of examples of projects that were either completed late or finished over budget, and were still considered successful (Shenar et. al 1996). Several studies have been conducted to define the variables and conditions responsible for project success in an attempt to create a recipe for use on future construction projects.

An often overlooked aspect of project success is the level of achievement or accomplishment received by a project's stakeholders. In the final analysis, if a project is to be perceived as successful, then its stakeholders must be satisfied. Stakeholders are those people who have an interest in a company's or organization's affairs (Sinclair 1995). By definition, stakeholders include a wide spectrum of people with varying reasons for having an interest in a construction project. Therefore, projects seek to satisfy a multiplicity of stakeholders, each with very different needs. The cost and schedule performance metrics associated with project success are typically not equally important to all stakeholders and are not, by themselves, adequate measures of stakeholder success. Against this backdrop, it is hardly surprising that there are numerous failures where the project does not meet the expectations of stakeholders (Dallas 2002).

Understanding the needs of stakeholders and attributes that impact stakeholder success is crucial for the successful delivery of a project by a management team. Through a holistic approach, this research attempts to identify and quantify the levels of stakeholder success attained according to varying project characteristics and levels of technology use.

The degree of stakeholder success is measured against construction industry characteristics and also against other salient performance parameters of projects. The relationships between stakeholder success and both industry and project performance characteristics are assessed. The degree of technology use on a construction project at both the project level and the work function level is analyzed to evaluate the relationship between technology incorporation and stakeholder success.

1.2 Purpose and Objectives

The purpose of this research is to better understand under what conditions stakeholder success occurs. This was accomplished by examining data from a diverse sample of construction projects. The data was analyzed from four parallel perspectives. The first perspective examined project characteristics for links between the rates of stakeholder success and project type. The second perspective analyzed relationships between stakeholder success rates and other project performance variables. The third perspective examined the degree of technological tools used at the project level to evaluate any correlations between automation integration and level of stakeholder success. Finally the project

technology use at the work function level was compared to levels of stakeholder success for any associations.

Thus, the objectives of this research are to:

1) Analyze stakeholder success rates as measured against such project characteristics as size, type of project, industry sector, ownership, and initial site.
2) Analyze stakeholder success rates in comparison with cost and schedule success measures.
3) Analyze relationships between project technology usage and stakeholder success at the project level.
4) Analyze relationships between project technology usage and stakeholder success at the work function level.

1.3 SCOPE LIMITATIONS

The data collected for this research contains material related to three different levels of project management. The first level is the project level, followed by the phase level, and the structure concludes with the work function level. Each of these levels increase in complexity and detail as you move from project level to the work function level. The research presented in this thesis focuses on only two of the three levels. The first level analyzed is the project level to determine what global project metrics pertaining to stakeholder success. The second level analyzed in this thesis is the work function level. The work function level is analyzed with respect to the project level technology usage to

assess the degree to which project technology use in day to day project items affects the overall assessment of stakeholders determining a project is successful.

1.4 STRUCTURE OF THIS THESIS

Chapter 2 will discuss the research methodology to include a brief description of the data, the collection methods, and the methods used to analyze the data. The results of an analysis of stakeholder success with respect to project characteristics are presented in Chapter 3, while Chapter 4 contains the results of an analysis of stakeholder success with respect to individual project performance variables. Chapter 5 discusses the results of an analysis of stakeholder success experienced when different levels of technology are used on the project. The results of correlations between the level technology use on selected project work functions and stakeholder success are presented in Chapter 6. The author's key conclusions are reiterated and recommendations for future research are presented in Chapter 7.

Chapter 2: Research Methodology

2.1 Research Process

This research was divided into three phases. Figure 2-1 presents an overview of the research steps. Phase 1 involved becoming familiar with previous studies and data collection as well as establishing the research goals and objectives. Phase 2 included a four part analysis of the collected data. Part one analyzed the data obtained for stakeholder success as it correlates to project characteristic variables. Part two consisted of analyzing the stakeholder success data as it correlates to specific project performance variables. Part three plotted the relationship between project stakeholder success and the project Integration and Automation index while part four charted the relationships between selected work functions and project stakeholder success. Phase 3 consisted of examining the data to further explain any evident trends in stakeholder success. A flow chart presenting the analysis logic is presented in Figure 2-2.

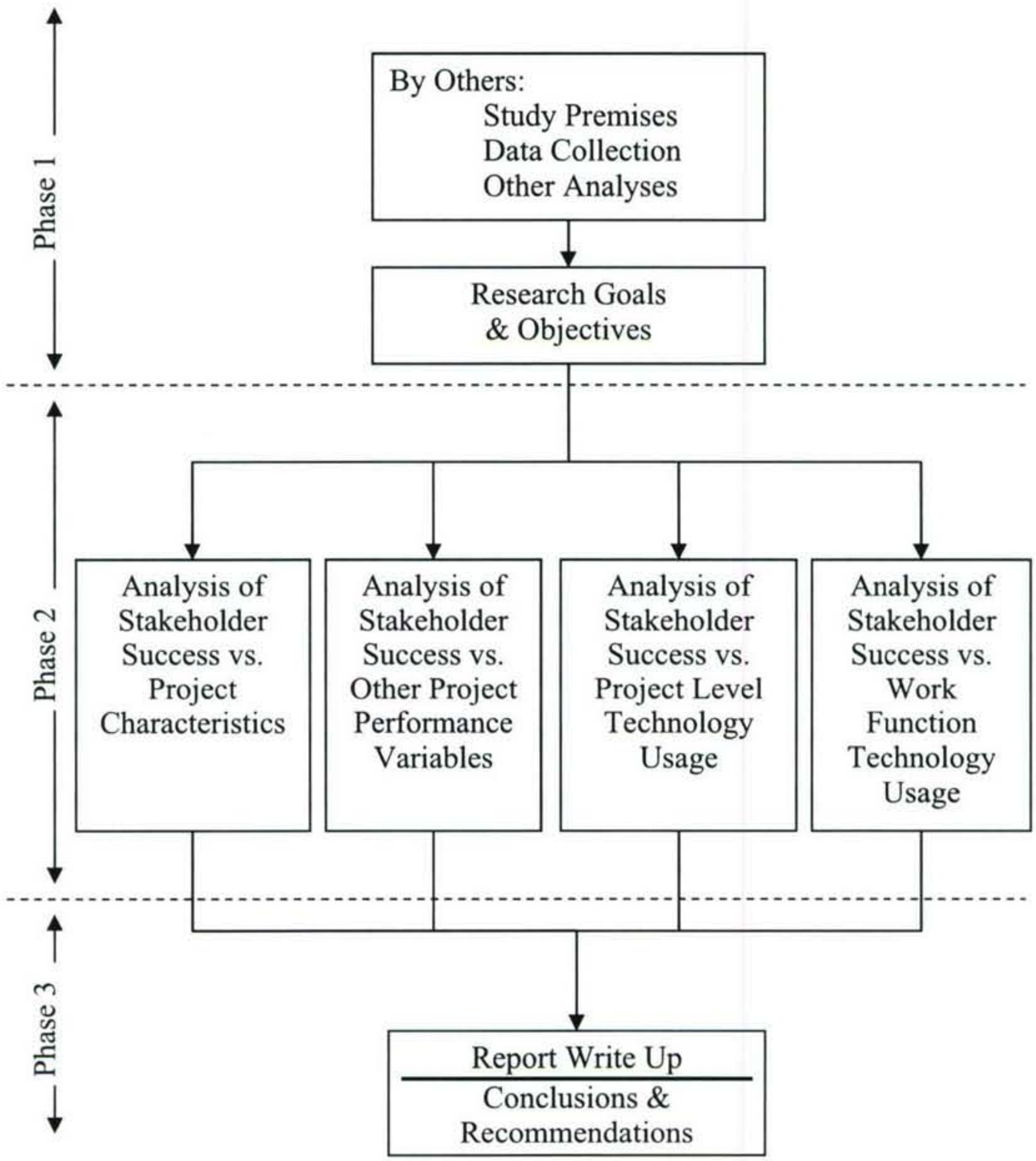

Figure 2-1: Research Steps

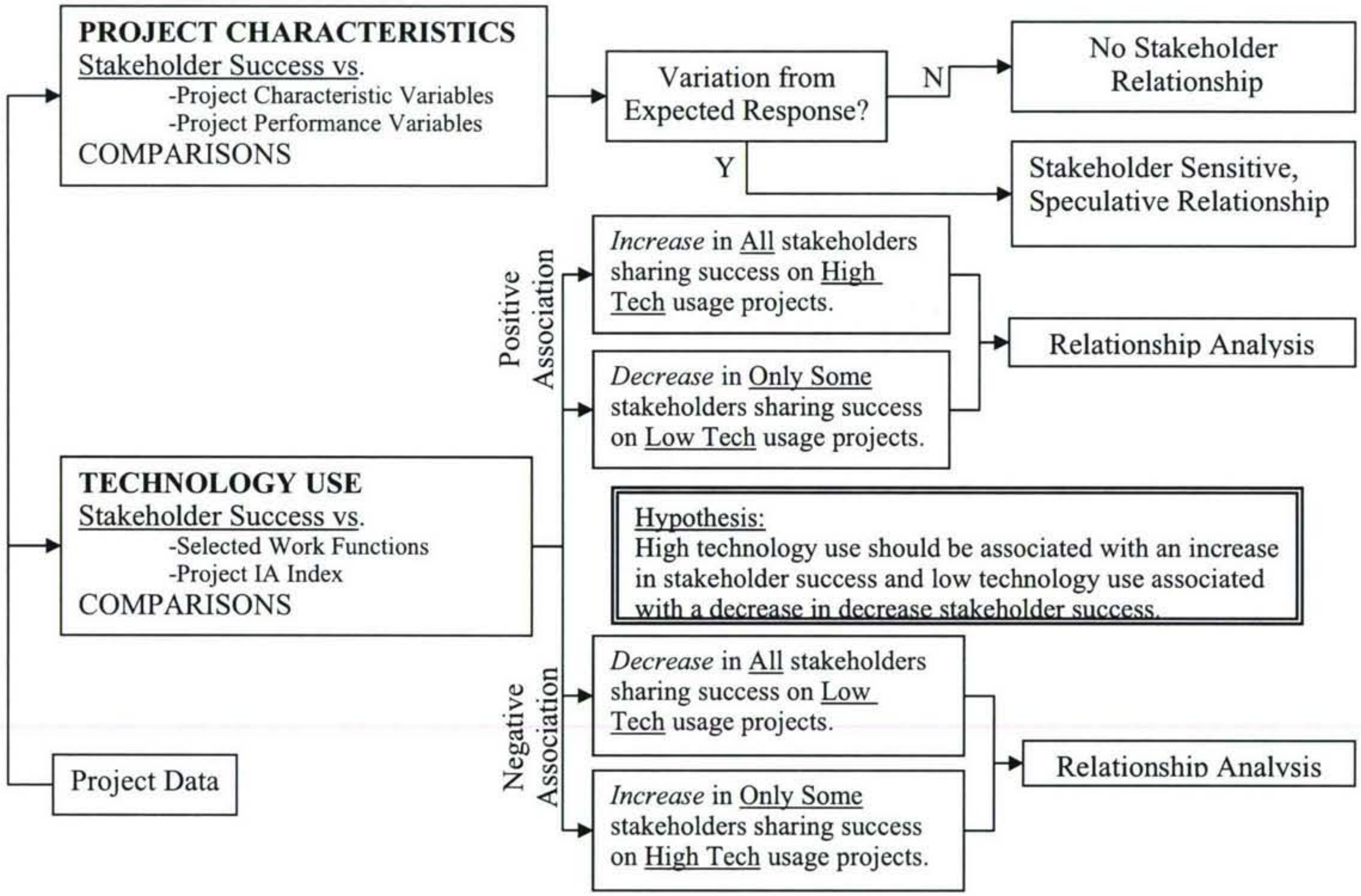

Figure 2-2: Logic of Analysis

2.2 PREVIOUS DATA COLLECTION AND DESCRIPTION

The data analyzed in this thesis was collected from a survey issued to a nation-wide representative sample of the construction industry between October 1998 and August 1999. The purpose of the survey was to investigate the extent to which integration and automation technologies are being used in executing capital facility projects (O'Connor et. al. 2000). A complete presentation of the study background, objectives, scope, survey structure, data collection methods, data collection results, index computation methods, and data analysis methods are found in the Center for Construction Industry Studies (CCIS) Report Number 16 by James T. O'Connor, Mark E. Kumashiro, Kieth A. Welch, Shane P. Hadeed, Kristen E. Braden, and Mandar J. Deogaonkar. Appendix A contains the final version of the survey form used to collect the data. Welch's thesis provides a complete discussion of the development and pilot testing of the data collection tool (Welch 1998).

The salient points regarding the data collection and research methodology are (O'Connor and Won 2001):

- Data collected and analyzed are project-specific (rather than organization specific).
- Data were collected from 209 projects and are believed to be representative of the U.S. industry.
- With the exception of low-volume home building operations, all project types were sought out for inclusion in the study.

- Data were collected through personal interviews but with the use of a survey form.
- 29 major metropolitan areas in 24 different U.S. states were visited for the purpose of collecting data.
- The data collection is based on assessment of technology usage on 68 different yet common project work functions.
- The primary statistic computed and analyzed is the integration/automation (IA) technology use index, which is computed on a 0 to 10 point scale.
- In computing both phase- and project-level IA indices (both of which are reported in previous reports), steps were taken to ensure the data representativeness was not threatened by missing data. Details on this are provided in O'Connor et. al. (2000) CCIS report 16.
- In computing phase-level indices, each work function is weighted equally.
- In computing project-level indices, each phase is weighted equally.
- Two broad classes of work functions are investigated: 1) tasks for automation and 2) task-to-task integration links. Details are provided in O'Connor et. al. (2000) CCIS report 16.
- Both Task Automation and Integration Link IA indices have been computed at both the phase and overall project levels.

To determine the level of integration and automation technology used during the execution of the construction project, the data collection tool required

the respondent to evaluate the level of technology used on each of 68 work functions defined by the survey. These work functions were grouped into six project phases: Front End, Design, Procurement, Construction Management, Construction Execution, and Start-up Operations & Maintenance. Table 2-1 shows the distribution of these work functions for each phase (O'Connor et. al. 2000).

Table 2-1: Distribution of Work Functions by Phase

Phase	Description	Number of Work Functions
1	Front End	6
2	Design	14
3	Procurement	12
4	Construction Management	15
5	Construction Execution	11
6	Start-up, Operations & Maintenance	10
Total		**68**

The answers provided for each work function were rolled up into a Phase Integration and Automation (IA) index which is a value between 0 and 10 with 10 representing the highest use of technology in the *phase*. The Phase IA index values were used to compute a Project IA index to assess the level of technology use at the project level in a similar fashion. Like the Phase IA index, the Project IA index is a value between 0 and 10 with 10 representing the highest use of technology on the *project*. A complete definition and discussion of the methods and logic behind the computation of the Phase IA index and the Project IA index is found in Kumahsiro's thesis (1999) and for brevity will not be repeated here.

In addition to being grouped into one of the six project phases, each work function was categorized as either a Task Automation (TA) work function or an Integration Link (IL) work function. A TA work function is one that is a candidate for possible automation because it reduces the amount of human effort required to accomplish the task's objectives. Integration Link work functions are the means by which information is conducted from one discrete task to the next (Yang 2003). When completing the survey, respondents did not know if a work function was either a TA work function or an IL work function but they did know which phase each work function represented. Appendix B delineates the classification of each work function and identifies the scope of each work function.

2.3 Research Goals and Objectives

Identification of trends resulting from relationships observed between project variables and stakeholder success is the primary goal of this research. This is accomplished through the following objectives:

1) Analyze stakeholder success rates as measured against such project characteristics as size, type of project, industry sector, ownership, and initial site.
2) Analyze stakeholder success rates in comparison with cost and schedule success measures.
3) Analyze relationships between project technology usage and stakeholder success at the project level.

4) Analyze relationships between project technology usage and stakeholder success at the work function level.

2.4 Relationships Between Project Characteristics and Stakeholder Success

Stakeholder success was measured against two categories of project variables. The first category consists of variables describing the characteristics of a project. There are seven primary project characteristic variables: Industry Sector, Total Installed Cost, Owner Regulation, Initial Site, Project Typicality, Personnel Experience, and Respondent Perspective. The variables and their purpose can be defined as follows:

1. Industry Sector – This variable divides the projects surveyed into three main sectors: Buildings, Industrial, and Infrastructure. The data collection tool asks participants to classify the project into one of these three categories.
2. Total Installed Cost – This variable is used to classify the size of the project. A project belongs in one of five cost categories: <$5 Million, $5-20 Million, $20-50 Million, $50-100 Million, and >$100 Million.
3. Owner Regulation – This variable distinguishes Private projects from Public projects.

4. Initial Site – The state of the project site at the beginning of the project is characterized by this variable. Three possible states were used: Greenfield (new), Renovation, and Expansion.
5. Project Typicality – For each project assessment, study participants were asked to rate the overall degree of technology usage for the project compared to the company norm. Two optional responses were provided: Typical or Advanced.
6. Respondent Experience – This is a measure of the length of time the survey respondent has spent in the construction industry.
7. Respondent Perspective – This variable identifies what facet of the project delivery team the respondent is from and thus their perspective towards the project. The options available are the business unit, operations, or the project management team.

The purpose of using the project characteristic variables is to ascertain if a particular segment or population of the construction industry (e.g. public or private), experience significantly greater levels of stakeholder success than other segments. Identification of a strong relationship will warrant further analysis to then answer the question of why one population of the construction industry appears to share more stakeholder success than another.

For each of the seven project characteristic variables, a matrix was developed to assist in identifying which combinations differed from an expected

normal response. The possible responses for the variable were placed in a column along the y axis and the possible stakeholder success responses were placed along the x axis in a row creating a 2, 3, 4, or 5 x 3 matrix depending on the variable being studied.

The data collection survey provided three choices for respondents to classify the level of stakeholder success achieved on the project. The available responses to choose from are All (A), Nearly All (NA), or Only Some (OS) project stakeholders shared in project success. Not every project characteristic variable analyzed had a response in both the variable being reviewed and the stakeholder success classification. The project characteristic variable and stakeholder success responses received range from 181 to 190 dependant upon the particular variable being studied.

Each of the project characteristic variables was segregated into the three stakeholder success classification and the stakeholder success rates for each classification were computed. An example of a project variable stakeholder success rate calculation using the industrial variable of the industry sector characteristic and the responses received for only some stakeholder success follows:

Project Characteristic Variable:	***Only Some Stakeholder Success Responses Received (this variable):***		***Total Stakeholder Success Responses Received (this variable):***		***Only Some Stakeholder Success Response Rate:***
Industry Sector -Industrial	**11**	÷	**47**	=	**.234 (23.4%)**

Once the project characteristic variable matrices were computed with stakeholder success rates, the mean stakeholder success rate and standard deviation was calculated for each stakeholder success category. The mean stakeholder success rate formed the baseline or expected stakeholder success rate used for relationship analysis.

Using the baseline stakeholder success rates and the standard deviations, measurement criteria for identifying any meaningful deviations among the responses received from the survey were established. A meaningful deviation for the purposes of this research is defined as less than or greater than one standard deviation from the mean value. One standard deviation is used because the purpose of this research is to identify relationships between construction project aspects and stakeholder success, not to prove correlations between project characteristics and stakeholder success to a statistically significant value.

A comparative analysis of the stakeholder success rates for each project characteristic was performed to identify which areas provide meaningful deviations according to the measurement criteria, thus indicating a relationship between that variable and the level of stakeholder success attained. To be considered a meaningful deviation more than one stakeholder success rate of a project characteristic variable had to exceed the measurement criteria.

2.5 RELATIONSHIPS BETWEEN OTHER PROJECT PERFORMANCE VARIABLES AND STAKEHOLDER SUCCESS

The second category of variables against which stakeholder success was measured is a selection of individual project performance variables. These variables were chosen to attempt to identify which project specific performance attributes factor into determining the level of stakeholder success. Unlike the project characteristic variables, these variables are common to all projects regardless of industry sector or project type. There are four individual variables: Cost Performance, Schedule Performance, Operations Start, and Project Safety. These variables and their purpose are defined as follows:

1. Cost Performance – This variable indicates if the total installed cost of the project was above, below, or essentially the same as the authorized budget.
2. Schedule Performance – This variable is used to determine which projects were completed earlier, later, or essentially the same as the planned project completion date.
3. Operations Start – Used to identify the projects that had an operations start date earlier, later, or essentially the same as the planned start date.
4. Project Safety – This variable identifies any projects that had an Occupational Safety and Health Administration (OSHA) reportable injuries during the project.

A matrix was developed for each variable similar to those developed for the project characteristic variables to assist in identifying which combinations of stakeholder success rates and project specific variables differed from the expected normal response. Again, measurement criteria was established using the same methodology as before and a comparative analysis of the stakeholder success rates of each project performance variable was performed.

2.6 Relationships Between Project Level Technology Usage and Stakeholder Success

To evaluate links between stakeholder success rates experienced and the level of technology used on the project a similar method to the project characteristic analysis was employed. The primary metric used to analyze this link was the Project Integration and Automation (IA) index. The Project IA index is a metric on a scale of 0 to 10 that measures the overall level of integration and automation technology used on the project. The Project IA Index was measurable in 181 of the 209 project survey responses. The mean Project IA index of these 181 projects and the standard deviation was computed. Using the standard deviation, breakpoints were established to classify the use of technology as low, medium, or high. A project with an IA index greater than the mean plus one standard deviation is classified as having high technology use. Likewise, a project with an IA index less than the mean IA index minus one standard deviation is classified as having low technology use. Everything in between these two values is considered to have medium technology use.

Using these technology breakpoints, a matrix was established with the technology use breakpoints on the y axis or columns and stakeholder success rates on the x axis or rows. The fields were filled according to the number of corresponding stakeholder success values. The matrix was comparatively analyzed according to the expected response rates and measurement criteria discussed in section 2.4 for any meaningful deviations.

2.7 Relationships Between Work Function Technology Usage and Stakeholder Success

The survey presented the respondents an opportunity to reply on the level of technology used on 68 various work functions. A hypothesis was developed to speculate which work functions are stakeholder success sensitive based on the project technology use level for each work function. The first part of the hypothesis was to evaluate each work function according to how an increase in technology use in that particular work function would affect historical metrics of project success. Specifically the following question was asked of each work function: "Will an increase in technology usage in the work function improve or strongly improve reduced project cost, reduced project completion time, an increase in project quality or an increase in the project/facility performance upon completion?"

The first part of the hypothesis narrowed the work functions suspected of being stakeholder success sensitive from 68 to 35. The 35 work functions were further evaluated using the data collected to determine if stakeholder success is sensitive to the employment of increased technology use in the work function.

Similar to the project characteristic variables, the number of work function and stakeholder responses received varied depending on the particular work function being studied. The responses range from 73 to 163. This response fluctuation necessitated a recalculation of the expected values as the default values will vary from those previously calculated. The work function mean response rates and the standard deviation of these rates was calculated considering only the responses provided for each of the 68 work functions.

A new measurement criterion was established to use for each work function comparison analysis. This criterion highlighted any meaningful deviations in the success rates among the responses received from the survey. Again, a meaningful deviation for the purposes of this research is less than or greater than one standard deviation from the mean value. Meaningful deviations were analyzed to determine the existence or lack of relationships between the degree of technology use and stakeholder success in construction projects.

Chapter 3: Project Characteristic Variable Analysis

This chapter addresses the associations between stakeholder success and the construction project characteristic variables. Stakeholder success responses are presented and analyzed according to each of the five characteristic variables discussed earlier: total installed cost (TIC), industry sector, initial site, project typicality, and owner regulation. A comparative analysis to determine meaningful variations from expected responses was conducted. This analysis resulted in three possible outcomes: 1) stakeholder success rate greater than expected rate, 2) stakeholder success rate equal to the expected rate, and 3) stakeholder success rate less than the expected rate. The results of the analysis and insights into their meaning are presented here.

3.1 Descriptive Statistics

The distribution of stakeholder success responses was categorized in a matrix according to the responses given for each project characteristic variable. The aggregate stakeholder success responses for each project characteristic variable range from a low of 2 responses for those projects with a total installed cost of \$50 million to \$100 million dollars where only some stakeholders shared success to a high of 74 responses for those projects using typical levels of technology where all stakeholders shared success. The mean stakeholder success response across all project characteristic variables is 20.6 with a standard deviation of 16.16.

Of the 209 survey responses, 190 provided a response in the stakeholder success classification. Table 3-1 provides a breakdown of the responses received by number of responses and percentages of total responses received.

Table 3-1: Stakeholder Success Descriptive Statistics

Stakeholder success	N	%
All	95	50.0%
Nearly All	64	33.7%
Only Some	31	16.3%

Not every project characteristic variable analyzed had a response in both the project characteristic variable being reviewed and the stakeholder success classification. The project characteristic variable and stakeholder success responses received range from 181 to 190 depending on the particular variable being studied. This fluctuation in responses results in a slightly different baseline percentage or default value from those in Table 3-1 to use for analysis. Table 3-2 presents the baseline percentages and the standard deviation of these stakeholder success response percentages obtained after adjusting to consider only the responses provided for each of the eleven project variables (project characteristic and project performance variables) studied.

Table 3-2: Stakeholder Success per Project Variable Mean Values

Stakeholder success	Rate (%)	Std Dev (%)
All	50.02%	7.14%
Nearly All	32.93%	6.93%
Only Some	17.05%	4.67%

3.2 Measurement Criterion

The stakeholder success rates in Table 3-2 form an established pattern of expected responses for each variable comparison. These values were used to identify any meaningful deviations among the responses received from the survey. A meaningful deviation for the purposes of this research is *less than or greater than* one standard deviation from the mean value. One standard deviation is used because the purpose of this research is to identify trends in the construction project industry that affect stakeholder success, not to prove correlations between project aspects and stakeholder success to a statistically significant value.

Boundaries or measurement criterion were established using the mean stakeholder success rates and the standard deviations. The upper and lower limits for each stakeholder success classification are presented in Table 3-3.

Table 3-3: Stakeholder Success Project Variable Analysis Boundaries

Stakeholder Success Level	Lower Limit (-1 Std. Dev.)	Expected Value	Upper Limit (+1 Std. Dev.)
All	42.88%	50.02%	57.16%
Nearly All	26.00%	32.93%	39.86%
Only Some	12.38%	17.05%	21.72%

3.3 Comparative Analysis Results and Insights

A comparative analysis of the stakeholder success rates for each project characteristic variable identified which areas provide meaningful deviations. To be considered meaningful for further analysis, more than one stakeholder success rate had to exceed the boundaries established in Table 3-3 in any one project characteristic variable category.

Tables 3-4 through 3-10 present the stakeholder success response rates received for each project characteristic variable and the results of the comparative variation analysis. Bold, underlined values with an arrow to illustrate direction in Tables 3-4 through 3-10 represent those exceeding the boundaries established in Table 3-3.

Table 3-4: Project Size vs. Stakeholder Success Response Rate

TIC ($M)	Stakeholder success: Only Some		Nearly all		All		Totals	
	%	N	%	N	%	N	%	N
<5	13.24	9	32.35	22	54.41	37	100.00%	68
5-20	**↑23.08**	12	34.62	18	**↓42.31**	22	100.00%	52
20-50	12.50	4	**↓21.88**	7	**↑65.63**	21	100.00%	32
50-100	**↓11.11**	2	**↑61.11**	11	**↓27.78**	5	100.00%	18
>100	**↑22.22**	4	33.33	6	44.44	8	100.00%	18
Total	16.49%	31	34.04%	64	49.47%	93	100.00%	188

Table 3-5: Industry Sector vs. Stakeholder Success Response Rate

Industry Sector	Stakeholder success: Only Some		Nearly all		All		Totals	
	%	N	%	N	%	N	%	N
Building	13.27	13	35.71	35	51.02	50	100.00%	98
Industrial	**↑23.40**	11	34.04	16	**↓42.55**	20	100.00%	47
Infrastructure	15.91	7	29.55	13	54.55	24	100.00%	44
Total	16.40%	31	33.86%	64	49.74%	94	100.00%	189

Table 3-6: Initial Site vs. Stakeholder Success Response Rate

Initial Site	Stakeholder success: Only Some		Nearly all		All		Totals	
	%	N	%	N	%	N	%	N
Greenfield	16.47	14	34.12	29	49.41	42	100.00%	85
Expansion	18.87	10	**↓24.53**	13	56.60	30	100.00%	53
Renovation	13.64	6	38.64	17	47.73	21	100.00%	44
Total	16.48%	30	32.42%	59	51.10%	93	100.00%	182

Table 3-7: Project Typicality vs. Stakeholder Success Response Rate

Project Typicality	Stakeholder success:							
	Only Some		**Nearly all**		**All**		Totals	
	%	**N**	%	**N**	%	**N**	%	**N**
Advanced	**↓9.38**	3	31.25	10	**↑59.38**	19	100.00%	32
Typical	17.45	26	32.89	49	49.66	74	100.00%	149
Total	16.02%	29	32.60%	59	51.38%	93	100.00%	181

Table 3-8: Owner Regulation vs. Stakeholder Success Response Rate

Owner Regulation	Stakeholder success:							
	Only Some		**Nearly all**		**All**		Totals	
	%	**N**	%	**N**	%	**N**	%	**N**
Private	15.08	19	34.13	43	50.79	64	100.00%	126
Public	19.05	12	33.33	21	47.62	30	100.00%	63
Total	16.40%	31	33.86%	64	49.74%	94	100.00%	189

Table 3-9: Respondent Experience vs. Stakeholder Success Response Rate

Respondent Experience	Stakeholder success:							
	Only Some		**Nearly all**		**All**		Totals	
	%	**N**	%	**N**	%	**N**	%	**N**
<5	**↓12.00**	3	32.00	8	56.00	14	100.00%	25
5-10	18.00	9	36.00	18	46.00	23	100.00%	50
10-20	20.00	12	**↑40.00**	24	**↓40.00**	24	100.00%	60
>20	14.58	7	**↓22.92**	11	**↑62.50**	30	100.00%	48
Total	16.94%	31	33.33%	61	49.73%	91	100.00%	183

Table 3-10: Respondent Perspective vs. Stakeholder Success Response Rate

Repsondent's Perspective	Stakeholder success:							
	Only Some		**Nearly all**		**All**		Totals	
	%	**N**	%	**N**	%	**N**	%	**N**
Business Unit	13.79	4	**↓24.14**	7	**↑62.07**	18	100.00%	29
Operations	**↑30.00**	3	30.00	3	**↓40.00**	4	100.00%	10
Project Team	15.89	24	35.76	54	48.34	73	100.00%	151
Total	16.32%	31	33.68%	64	50.00%	95	100.00%	190

The purpose of these analyses was to ascertain whether stakeholder success is associated with or has a relationship to any of the project characteristic variables. The analyses suggest that the total installed cost and to lesser extents the industry sector, project typicality respondent experience, and respondent perspective are related to the levels of stakeholder success attained on a project.

Further analyses of values that exceed the boundaries offer the following insights into possible stakeholder success relationships at the project characteristic level:

- Projects greater than $100 Million in total installed cost experience lower rates of stakeholder success, suggesting that stakeholder success is harder to achieve in high-dollar, more complex projects.
- The data suggests either stakeholders are more comfortable with mid-size projects or the construction-project management team is more effective at managing resources and delivering a successful project on mid-size projects.

- The projects with a TIC ranging from 5 to 20 million dollars offer a strong relationship to stakeholder success. Those projects with nearly all stakeholders experiencing success remains at the expected value while there is a large swing from those projects with all stakeholders experiencing success to projects with only some stakeholders experiencing success. This indicates a tendency for increasing stakeholder dissatisfaction among this industry demographic.
- The industrial building sector reports lower levels of stakeholder success.
- Surprisingly, the state of the initial site does not have a meaningful relationship with stakeholder success level of stakeholder success. This is a departure from the conventional wisdom that renovation and expansion projects are more difficult and complex and thus harder to achieve stakeholder success.
- Although still small in total numbers of projects incorporating advanced levels of technology, the link between those projects that do incorporate higher use of technology in the project life cycle and stakeholder success is stronger than those employing less use of technology.
- No consequential distinction can be drawn between public and private projects. This is interesting as public work is often viewed

as mismanaged which should increase the level of frustration amongst stakeholders and thus decrease stakeholder success.

- Survey respondents with greater than ten years of experience are more likely to experience higher levels of stakeholder success. This may be due to their previous exposure to unsuccessful projects and they are more forgiving when assessing current projects.
- In a contrast to information characterized by the operations start date, the respondent's perspective suggests that those in the operations segment of business received lower levels of stakeholder success.
- Those in the business unit are more likely to classify a project as successful to all stakeholders.

Chapter 4: Other Project Performance Variable Analysis

This chapter addresses the associations between stakeholder success and the individual project performance variables. Stakeholder success responses are presented and analyzed according to each of the four selected project performance variables discussed earlier: cost performance, schedule performance, operations start, and project safety. A comparative analysis to determine meaningful variations from expected responses was conducted. This analysis resulted in three possible outcomes: 1) stakeholder success rate greater than expected rate, 2) stakeholder success rate equal to the expected rate, and 3) stakeholder success rate less than the expected rate. The results of the analysis and insights into their meaning are presented here.

4.1 Descriptive Statistics

The distribution of stakeholder success responses was categorized in a matrix according to the responses given for each project performance variable. The aggregate stakeholder success responses for each project performance variable had a low of 3 responses received in the following combinations of project performance and stakeholder success level: only some stakeholders shared success and the operations start date was earlier than planned, only some stakeholders shared success and the respondent experience was less than five years, only some stakeholders shared success and the respondent's perspective was from the operations unit, and nearly all stakeholders shared success and

respondent's perspective was from the operations unit. The highest level of responses received was 73 for those projects with the respondent's perspective being in the project team indicating all stakeholders shared success. The mean stakeholder success response across all project performance variables is 19.4 with a standard deviation of 19.06.

4.2 Comparative Analysis Results and Insights

Again, using the default response percentages from Table 3-2 and the boundaries established by Table 3-3, the individual responses for each project performance variable were analyzed for any variations *greater than or less than* one standard deviation from the average or expected value. The boundaries previously established are repeated in Table 4-1 for convenience.

Table 4-1: Stakeholder Success Project Variable Analysis Boundaries

Stakeholder Success Level	Lower Limit (-1 Std. Dev.)	Expected Value	Upper Limit (+1 Std. Dev.)
All	42.88%	50.02%	57.16%
Nearly All	26.00%	32.93%	39.86%
Only Some	12.38%	17.05%	21.72%

Tables 4-2 through 4-5 contain the stakeholder success response rates received for each project performance variable and the results of the variation analysis. Bold, underlined values with an arrow indicating direction in Tables 4-2 through 4-5 represent those exceeding the boundaries established in Table 4-1.

Table 4-2: Cost Performance vs. Stakeholder Success Response Rate

Cost Performance	Stakeholder success:							
	Only Some		**Nearly all**		**All**		Totals	
	%	**N**	%	**N**	%	**N**	%	**N**
Under Budget	12.50	4	34.38	11	53.13	17	100.00%	32
Met Budget	16.06	22	35.04	48	48.91	67	100.00%	137
Over Budget	21.05	4	26.32	5	52.63	10	100.00%	19
Total	15.96%	30	34.04%	64	50.00%	94	100.00%	188

Table 4-3: Schedule Performance vs. Stakeholder Success Response Rate

Project Completion	Stakeholder success:							
	Only Some		**Nearly all**		**All**		Totals	
	%	**N**	%	**N**	%	**N**	%	**N**
Early	**↑26.09**	6	**↓21.74**	5	52.17	12	100.00%	23
On Time	13.67	19	35.25	49	51.08	71	100.00%	139
Late	**↑22.22**	6	33.33	9	44.44	12	100.00%	27
Total	16.40%	31	33.33%	63	50.26%	95	100.00%	189

Table 4-4: Operations Start vs. Stakeholder Success Response Rate

Operations Start:	Stakeholder success:							
	Only Some		**Nearly all**		**All**		Totals	
	%	**N**	%	**N**	%	**N**	%	**N**
Early	16.67	3	33.33	6	50.00	9	100.00%	18
On Time	16.67	20	32.50	39	50.83	61	100.00%	120
Late	13.79	4	37.93	11	48.28	14	100.00%	29
Total	16.17%	27	33.53%	56	50.30%	84	100.00%	167

Table 4-5: Project Safety vs. Stakeholder Success Response Rate

OSHA Reportable injuries	Stakeholder success:							
	Only Some		**Nearly all**		**All**		Totals	
	%	**N**	%	**N**	%	**N**	%	**N**
No	13.45	16	36.97	44	49.58	59	100.00%	119
Don't Know	15.00	3	35.00	7	50.00	10	100.00%	20
Yes	**↑<u>23.53</u>**	12	**↓<u>25.49</u>**	13	50.98	26	100.00%	51
Total	16.32%	31	33.68%	64	50.00%	95	100.00%	190

The purpose of these analyses was to ascertain if the level of stakeholder success achieved is associated with or has a relationship to specific project performance parameters. The analyses suggest that schedule performance, and project safety are related to the level of stakeholder success.

Further analyses of values that exceed the boundaries offer the following insights into possible stakeholder success relationships at the project performance level:

- Cost performance of a project does not have a meaningful relationship with the level of stakeholder success realized.
- A tradeoff appears to exist between completing a project early and the level of success achieved by the stakeholders.
- Unlike project completion, the timing of the operations start, which affects the bottom line of the owner, does not appear to be related to stakeholder success rates.

- Perhaps as expected, those projects with reportable safety mishaps reflect increasing stakeholder dissatisfaction.

Chapter 5: Project Technology Usage Analysis

The association between the level of stakeholder success attained and the overall degree of technology used during the execution of the project is addressed in this chapter. Stakeholder success responses are presented and analyzed according to selected categories of the Project Integration and Automation (IA) Index. Analysis of variation from expected stakeholder success rates indicates a possible connection between the use of technology at the project level and stakeholder success. Insights from the analysis are presented here.

5.1 Descriptive Statistics

The Project IA Index was measurable in 181 of the 209 projects assessed with the data collection tool. As previously discussed, the Project IA Index is a metric on a ten point scale that measures the overall level of integration and automation technology used on the project. The mean Project IA Index of these 181 projects is 3.89 with a standard deviation of 1.84. The minimum recorded Project IA Index value is 0.0 and the maximum value is 10.0. A correlation between the responses received for the Project IA Index and the rates of stakeholder success returns 169 projects that have a recordable Project IA Index and a stakeholder success level response. The mean of stakeholder success responses is 18.7 with a low aggregate response of 4 in the area of only some stakeholders sharing success and high level of technology used and a high

aggregate response of 59 in the area of all stakeholders sharing success and a medium level of technology used on the project.

Using the standard deviation, breakpoints were established to classify the use of technology as low, medium, or high. A project with an IA index greater than the mean plus one standard deviation, or 5.7 is classified as having high technology use. Likewise, a project with an IA index less than the mean IA index minus one standard deviation, or 2.1 is classified as having low technology use. Everything in between these two values is considered to have medium technology use. Table 5-1 summarizes these breakpoints.

Table 5-1: Technology Use Levels

Technology Use Level	Project IA Index
High	>5.7
Medium	2.1 – 5.69
Low	<2.1

5.2 Project Technology Use Comparison Analysis and Insights

An analysis was conducted using the technology level breakpoints established in Table 5-1 to highlight any link between the Project IA Index and rates of stakeholder success experienced. A matrix was established with the technology use breakpoints on the y axis and stakeholder success classification on the x axis. Tables 5-3 and 5-4 present the collective correlation between the stakeholder responses and the level of technology use. These tables present the information matrices both as the number of responses per category and as a

percentage of the level of technology use. The response rates in Table 5-4 were examined for any variation from the expected response rate using the boundaries established previously. These boundaries are repeated in Table 5-2 for convenience.

Table 5-2: Stakeholder Success Project Variable Analysis Boundaries

Stakeholder Success Level	Lower Limit (-1 Std. Dev.)	Expected Value	Upper Limit (+1 Std. Dev.)
All	42.88%	50.02%	57.16%
Nearly All	26.00%	32.93%	39.86%
Only Some	12.38%	17.05%	21.72%

Bold, underlined values with arrows indicating direction in Table 5-4 represent those rates that exceed the upper or lower limits of the expected response rate.

Table 5-3: Project IA Index vs. Stakeholder Success Responses

		Stakeholder Success - N			
		Only Some	**Nearly all**	**All**	**Total**
Project IA Index	**>5.7**	4	11	16	31
	2.1 - 5.69	15	40	59	114
	<2.1	6	6	12	24

Table 5-4: Project IA Index vs. Stakeholder Success Response Rate

		Stakeholder Success - Row %			
		Only Some	Nearly all	All	Total
Project IA Index	>5.7	12.90%	35.48%	51.61%	100%
	2.1 - 5.69	13.16%	35.09%	51.75%	100%
	<2.1	**↑25.00%**	**↓25.00%**	50.00%	100%

The purpose of these analyses was to determine if the degree of technology used on a project is connected to the level of stakeholder success achieved. The analyses suggest that in today's business world, the low levels of technology utilization at the project level are negatively linked to the level of success experienced by the stakeholders.

This is somewhat surprising as conventional wisdom and experience indicates people are resistant to the application of new and increased technology. There is usually a trend to be technology adverse in not only the construction industry but in life. The data suggests lower levels of technology use are associated with lower levels of stakeholder success. The data also indicates technology may be an asset to accomplishing stakeholder objectives and no longer an obstacle to progress. The reasons behind this are numerous and beyond the scope of this research.

The finding here correlates to the results of the data suggestions in Chapter 3 that Advanced technology use in projects is linked to increasing stakeholder success. Further research is warranted to explain these results. Work function level technology usage analyzed in Chapter 6 will highlight some reasons for this in more depth.

Chapter 6: Work Function Technology Usage Analysis

The relationships between individual work function technology usage and stakeholder success is analyzed in this chapter. The work functions are categorized into two broad classifications: Integration Link (IL) and Task Automation (TA). Integration Link work functions are the means by which information is conducted from one discrete task to the next. Task Automation work functions refer to those in which automation can reduce the amount of human effort required to accomplish the task's objectives (Yang 2003). Understanding how technology usage in everyday tasks interacts with the larger picture of stakeholder success may enable all levels of the workforce to create an environment more conducive to successful projects from the stakeholder's point of view. A stakeholder success variation comparison is applied to the level of technology usage employed for each work function and the results are presented here.

6.1 Work Function Screening

Each work function was scrutinized according to the work function's relations to project success metrics to screen the 68 work functions for further analysis. The screening was performed by the author and is based on conventional project management and delivery performance measurement. Each work function was evaluated according to how an increase in technology usage in that particular work function would affect common metrics of project success.

Specifically the following question was asked of each work function: "Will an increase in technology usage in the work function improve or strongly improve reduced project cost, reduced project completion time, an increase in project quality or an increase in the project/facility performance upon completion?" This rational analysis narrowed the work functions suspected of being stakeholder success-sensitive from 68 to 35. The 35 work functions and the results of the screening listed in Table 6-1. These 35 work functions were further evaluated using the data collected to determine if stakeholder success is sensitive to the employment of increased technology usage in the work function. The purpose of the screening was to identify those work functions usually related to the level of project success to analyze their relationship to stakeholder success.

Table 6-1: Work Function Rational Screening Results

	ID	Work Function	↓Cost Sensitivity	↓Time Sensitivity	↑Quality Sensitivity	↑Facility Operating Performance
INTEGRATION LINK	104	Estimate a budget from the scope of work.	X			
	105	Develop a milestone schedule from the scope of work.		X		
	201	Designers access supplier information in order to select components.	X	X	X	X
	211	Detect physical interference between systems.	X	X	X	X
	303	Link quantity survey data to the cost estimating process.	X	X		
	304	Link supplier cost quotes to the cost estimating process.	X	X		
	307	Develop and transmit requests for proposals to suppliers and subs.	X	X		
	308	Prepare and submit shop drawings.		X	X	
	309	Acquire and review shop drawings; send response.		X	X	
	311	Monitor the progress of fabricators.	X	X	X	
	402	Track field work progress and labor cost code charges.	X	X		X
	405	Keep all project team members up to date on construction progress.	X	X		X
	406	Track the inventory of materials on site.	X	X	X	X
	407	Link field material managers to suppliers.	X	X	X	X
	409	Work crews submit and receive answers to RFIs.		X		X
	411	Communicate design changes to field personnel.		X	X	X
	509	Acquire and record laboratory test information.			X	X
	604	Track and analyze the maintenance history of important equipment.	X		X	X
	605	Develop maintenance plans from maintenance history data.	X		X	X
	607	Facility operators request maintenance or modifications.	X	X		X
	609	Monitor/Track/Control facility energy usage.	X			X
	610	Monitor environmental impact of facility operations.	X			X
TASK AUTOMATION	101	Conduct market analysis or need analysis for a new facility.	X	X		
	205	Generate facility floor plans.	X	X		
	206	Design the fluid transport system and related drawings.	X	X	X	
	207	Design the structural system and related drawings.	X	X	X	
	208	Design the electrical system and related drawings.	X	X	X	
	209	Design the HVAC system and related drawings.	X	X	X	
	212	Prepare project specifications.		X		
	214	Track design progress.		X	X	X
	306	Develop the milestone schedule.		X		X
	401	Develop the construction schedule.		X		X
	408	Develop short term work schedules based on resource availability.		X	X	X
	602	Train facility operators.			X	X
	606	Monitor and assess equipment operations.				X

6.2 Descriptive Statistics

The 22 IL work functions selected for detailed analysis had a mean of 14.4 responses with a standard deviation of 14.6. The responses range from a low of 0 in work function 610 with high technology usage and only some stakeholders experiencing success to a high of 57 in work function 411 with a medium level of technology usage and all stakeholders experiencing success. For the 13 TA work functions selected for detailed analysis, there was a mean of 12.8 responses with a standard deviation of 13.2. The low response of 1 appears in several work functions, primarily when high technology is used and only some stakeholders experience success. The high is 57, also appearing in several work functions, with a medium level of technology usage and all stakeholders experiencing success.

6.3 Measurement Criterion

Similar to the project characteristic variables, the number of work function and stakeholder responses received varied depending on the particular work function being studied. The responses range from 73 to 163. This response fluctuation necessitated a recalculation of the expected values as the default values varied from those presented in Table 3-2. Table 6-2 presents the baseline percentages and the standard deviation of these response percentages obtained after adjusting to consider only the responses provided for each of the 68 work functions.

Table 6-2: Stakeholder Success per Work Function Mean Values

Stakeholder success	Rate (%)	Std Dev (%)
All	53.72%	6.34%
Nearly All	30.29%	6.83%
Only Some	15.99%	5.87%

The values in Table 6-2 form an established pattern of expected responses from the entire sample for each work function comparison. These values were used to identify any meaningful deviations among the responses received from the survey. A meaningful deviation for the purposes of this research is defined as *less than or greater than* one standard deviation from the mean value. Table 6-3 represents the boundaries established by adding and subtracting one standard deviation to the expected stakeholder success rate forming a measurement criterion for a work function comparative analysis.

Table 6-3: Work Function Stakeholder Success Rate Comparative Analysis Boundaries

Stakeholder Success Level	Lower Limit (-1 Std. Dev.)	Expected Value	Upper Limit (+1 Std. Dev.)
All	47.38%	53.72%	60.06%
Nearly All	23.46%	30.29%	37.12%
Only Some	10.12%	15.99%	21.86%

6.4 Integration Link Work Function Comparison Results and Insights

Similar to the analyses performed in Chapters 3 and 4, the measurement criteria established in table 6-3 was used to analyze each work function selected. Table 6-4 presents the number of stakeholder success responses by Integration Link work function and technology usage category. Table 6-5 presents the stakeholder success response rates received for each Integration Link work function selected for analysis and the results of the variation analysis. Bold, underlined values with arrows indicating direction in Table 6-5 represent those exceeding the one standard deviation boundaries established in Table 6-3.

Table 6-4: IL Work Function Technology Usage Level vs. Stakeholder Success Responses

IL Work Function	Technology Level (Project IA Index)		Stakeholder Success (N)		
			Only Some	Nearly All	All
104	High	>5.7	4	9	15
	Med	2.1 - 5.69	13	37	56
	Low	<2.1	3	5	9
105	High	>5.7	4	9	15
	Med	2.1 - 5.69	13	39	55
	Low	<2.1	4	6	9
201	High	>5.7	3	9	13
	Med	2.1 - 5.69	12	27	38
	Low	<2.1	2	3	6
211	High	>5.7	2	7	13
	Med	2.1 - 5.69	9	29	44
	Low	<2.1	3	3	7
303	High	>5.7	3	6	13
	Med	2.1 - 5.69	11	35	51
	Low	<2.1	5	5	11
304	High	>5.7	3	9	13
	Med	2.1 - 5.69	12	35	53
	Low	<2.1	6	6	12
307	High	>5.7	2	9	13
	Med	2.1 - 5.69	14	35	56
	Low	<2.1	6	6	12

IL Work Function	Technology Level (Project IA Index)		Stakeholder Success (N)		
			Only Some	Nearly All	All
308	High	>5.7	3	8	14
	Med	2.1 - 5.69	13	33	50
	Low	<2.1	5	5	9
309	High	>5.7	3	9	15
	Med	2.1 - 5.69	14	34	55
	Low	<2.1	5	6	10
311	High	>5.7	3	8	12
	Med	2.1 - 5.69	12	32	45
	Low	<2.1	5	5	10
402	High	>5.7	3	9	15
	Med	2.1 - 5.69	12	38	55
	Low	<2.1	6	6	10
405	High	>5.7	4	9	16
	Med	2.1 - 5.69	15	40	56
	Low	<2.1	5	6	12
406	High	>5.7	4	8	12
	Med	2.1 - 5.69	13	32	45
	Low	<2.1	5	5	12
407	High	>5.7	2	7	11
	Med	2.1 - 5.69	9	29	36
	Low	<2.1	5	6	11
409	High	>5.7	2	7	16
	Med	2.1 - 5.69	15	40	52
	Low	<2.1	6	5	8
411	High	>5.7	3	9	16
	Med	2.1 - 5.69	13	40	57
	Low	<2.1	5	6	11

IL Work Function	Technology Level (project IA index)		Stakeholder Success (N)		
			Only Some	Nearly All	All
509	High	>5.7	3	5	14
	Med	2.1 - 5.69	11	34	50
	Low	<2.1	4	1	10
604	High	>5.7	1	2	8
	Med	2.1 - 5.69	9	25	37
	Low	<2.1	4	2	6
605	High	>5.7	1	3	8
	Med	2.1 - 5.69	10	21	37
	Low	<2.1	2	2	6
607	High	>5.7	1	4	8
	Med	2.1 - 5.69	9	24	36
	Low	<2.1	3	4	7
609	High	>5.7	1	2	8
	Med	2.1 - 5.69	9	20	31
	Low	<2.1	2	1	6
610	High	>5.7	0	2	6
	Med	2.1 - 5.69	8	21	29
	Low	<2.1	2	2	6

Table 6-5: IL Work Function Technology Usage Level vs. Stakeholder Success Rate

IL Work Function	Technology Level (Project IA Index)		Stakeholder Success (%)		
			Only Some	Nearly All	All
104	High	>5.7	14.29	32.14	53.57
	Med	2.1 - 5.69	12.26	34.91	52.83
	Low	<2.1	17.65	29.41	52.94
105	High	>5.7	14.29	32.14	53.57
	Med	2.1 - 5.69	12.15	36.45	51.40
	Low	<2.1	21.05	31.58	**↓47.37**
201	High	>5.7	12.00	36.00	52.00
	Med	2.1 - 5.69	15.58	35.06	49.35
	Low	<2.1	18.18	27.27	54.55
211	High	>5.7	**↓9.09**	31.82	59.09
	Med	2.1 - 5.69	10.98	35.37	53.66
	Low	<2.1	**↑23.08**	**↓23.08**	53.85
303	High	>5.7	13.64	27.27	59.09
	Med	2.1 - 5.69	11.34	36.08	52.58
	Low	<2.1	**↑23.81**	23.81	52.38
304	High	>5.7	12.00	36.00	52.00
	Med	2.1 - 5.69	12.00	35.00	53.00
	Low	<2.1	**↑25.00**	25.00	50.00
307	High	>5.7	**↓8.33**	**↑37.50**	54.17
	Med	2.1 - 5.69	13.33	33.33	53.33
	Low	<2.1	**↑25.00**	25.00	50.00
308	High	>5.7	12.00	32.00	56.00
	Med	2.1 - 5.69	13.54	34.38	52.08
	Low	<2.1	**↑26.32**	26.32	**↓47.37**

IL Work Function	Technology Level (Project IA Index)		Stakeholder Success (%)		
			Only Some	Nearly All	All
309	High	>5.7	11.11	33.33	55.56
	Med	2.1 - 5.69	13.59	33.01	53.40
	Low	<2.1	**↑23.81**	28.57	47.62
311	High	>5.7	13.04	34.78	52.17
	Med	2.1 - 5.69	13.48	35.96	50.56
	Low	<2.1	**↑25.00**	25.00	50.00
402	High	>5.7	11.11	33.33	55.56
	Med	2.1 - 5.69	11.43	36.19	52.38
	Low	<2.1	**↑27.27**	27.27	**↓45.45**
405	High	>5.7	13.79	31.03	55.17
	Med	2.1 - 5.69	13.51	36.04	50.45
	Low	<2.1	21.74	26.09	52.17
406	High	>5.7	16.67	33.33	50.00
	Med	2.1 - 5.69	14.44	35.56	50.00
	Low	<2.1	**↑22.73**	**↓22.73**	54.55
407	High	>5.7	**↓10.00**	35.00	55.00
	Med	2.1 - 5.69	12.16	**↑39.19**	48.65
	Low	<2.1	**↑22.73**	27.27	50.00
409	High	>5.7	**↓8.00**	28.00	**↑64.00**
	Med	2.1 - 5.69	14.02	**↑37.38**	48.60
	Low	<2.1	**↑31.58**	26.32	**↓42.11**
411	High	>5.7	10.71	32.14	57.14
	Med	2.1 - 5.69	11.82	36.36	51.82
	Low	<2.1	**↑22.73**	27.27	50.00
509	High	>5.7	13.64	**↓22.73**	**↑63.64**
	Med	2.1 - 5.69	11.58	35.79	52.63
	Low	<2.1	**↑26.67**	**↓6.67**	**↑66.67**

IL Work Function	Technology Level (Project IA Index)		Stakeholder Success (%)		
			Only Some	Nearly All	All
604	High	>5.7	**↓9.09**	**↓18.18**	**↑72.73**
	Med	2.1 - 5.69	12.68	35.21	52.11
	Low	<2.1	**↑33.33**	**↓16.67**	50.00
605	High	>5.7	**↓8.33**	25.00	**↑66.67**
	Med	2.1 - 5.69	14.71	30.88	54.41
	Low	<2.1	20.00	**↓20.00**	60.00
607	High	>5.7	**↓7.69**	30.77	**↑61.54**
	Med	2.1 - 5.69	13.04	34.78	52.17
	Low	<2.1	21.43	28.57	50.00
609	High	>5.7	**↓9.09**	**↓18.18**	**↑72.73**
	Med	2.1 - 5.69	15.00	33.33	51.67
	Low	<2.1	**↑22.22**	**↓11.11**	**↑66.67**
610	High	>5.7	**↓0.00**	25.00	**↑75.00**
	Med	2.1 - 5.69	13.79	36.21	50.00
	Low	<2.1	20.00	**↓20.00**	60.00

The purpose of this analysis was to determine primarily if the degree of technology used in selected Integration Link work functions is strongly associated with the level of stakeholder success achieved. Once work function technology usage is determined to be strongly associated with stakeholder success, then evaluating the direction of association is prudent. Those Integration Link work functions associated with stakeholder success and the direction of the association are presented in Table 6-6.

Table 6-6: Stakeholder Success-Sensitive

IL Work Functions

ID	Description	Stakeholder Success Associated WFs	
		POSITIVE	NEGATIVE
		Increase in All share success & High Tech OR *Decrease* in Only Some share success & Low Tech	*Decrease* in All share success & High Tech OR *Increase* in Only Some share success & Low Tech
308	Prepare and submit shop drawings		X
402	Track field work progress and labor cost code charges		X
409	Work crews submit & receive answers to Requests for Information	X	X
509	Acquire and record laboratory test information	X	X
604	Track and analyze the maintenance history of important equipment	X	X
605	Develop maintenance plans from maintenance history data	X	
607	Facility operators request maintenance or modifications	X	
609	Monitor/track/control facility energy usage	X	X
610	Monitor environmental impact of facility operations	X	

Nine of the 22 Integration Link work functions analyzed are thought to be related to stakeholder success. Insights into each of these work functions include:

WF 308: Prepare and submit shop drawings

The administrative process of developing, acquiring, and submitting shop drawings efficiently and timely has ripple effects that often impact the critical path of a project. Lower use of technology for this process is associated with a decrease in the number of stakeholders experiencing success and thus a reinforcement of a project's schedule performance as an important metric.

WF 402: Track field work progress and labor cost code charges

Schedule and cost performance are arguably the two metrics most often reviewed. Accurate information regarding the progress of work and allocation of fiscal resources is crucial to managing a project effectively. The data reinforces the importance of using higher levels of technology to execute this work function. Those projects using a lower level of technology in this work function were tied to an increase in the level of dissatisfaction among stakeholders.

WF 409: Work crews submit and receive answers to Requests for Information

Answers to Requests for Information (RFI) often determine the execution of construction tasks. Late response to field inquiries can lead to a delay in the critical path. Therefore, submitting and receiving answers to RFIs are critical to

the successive completion of work items on time. Problems with RFIs compound from work item to work item. Perhaps it is no surprise that the data reinforces the importance of this work function. Stakeholders experience greater levels of success associated with this work function when the level of technology use is high which indicates the technology aids in the reduction of RFI turnaround time. Similarly stakeholders appear to be increasingly frustrated by this work function when there is a lower level of technology used.

WF 509: Acquire and record laboratory test information

Results of quality and other intermediate tests impact not only the current construction tasks but the execution of future tasks. Timely acquisition of results and quick access to test results are vital to the sequence of work, quality and performance of the product delivered by the project team. The data suggests mixed results regarding the use of technology for this work function and its relationship to stakeholder success. While a high level of technology use in this work function is associated with higher levels of stakeholder success, the reverse is not necessarily true. Interestingly, lower levels of technology use were associated with both increased stakeholder success and decreased stakeholder success.

WF 604: Track and analyze the maintenance history of important equipment

Proper maintenance of key equipment impacts the life cycle costs associated with a facility. The start-up portion of project delivery establishes the

foundation for future maintenance patterns. The data provides strong evidence supporting the use of higher technology in this work function. Those projects employing higher technology were coupled with an overwhelming percentage of stakeholders sharing success while those employing a lower level of technology were coupled with an increasing percentage of stakeholders dissatisfied or not sharing success.

WF 605: Develop maintenance plans from maintenance history data

An extension of work function 604 is to be able to organize, schedule, and execute future maintenance from past events. It is logical to assume that if the degree of technology use is related to the level of stakeholder success realized for how maintenance history is tracked and analyzed, the same would be true for the development of maintenance plans from that historical data. This assumption is supported by the analysis results.

WF 607: Facility operators request maintenance or modifications

The ability to tailor a facility to the end user is important to the success they realize for obvious reasons. Higher technology usage improves communication, eliminating misunderstandings and resulting in the delivery of a facility best suited to owner and user needs. This is reinforced by the data in realizing a relationship between high stakeholder success on the projects with higher technology use.

WF 609: Monitor/track/control facility energy usage

Efficient energy usage results in cost savings. Employing technology to monitor energy usage normally helps facilities operate more efficiently because of the reduction of labor required to perform monitoring. The data returns mixed results on using higher levels of technology in this work function. Similar to work function 509, the projects experiences high levels of stakeholder success in not only those using high levels of technology but also those using lower levels of technology. Perhaps technology use in this work function is independent to the level of stakeholder success.

WF 610: Monitor environmental impact of facility operations

A negative effect on the surrounding environment by a facility can result in steep fines or force future modifications to the facility. Likewise, positive environmental impacts can result in recognition and tax breaks for facility owners. The data overwhelmingly supports that increase in levels of technology use is linked to achieving higher levels of stakeholder success.

6.5 Task Automation Work Function Comparison Results and Insights

The analysis process used for the IL work functions was repeated when analyzing the 13 selected Task Automation work functions for stakeholder success relationships. Table 6-7 presents the number of stakeholder success responses by Integration Link work function and technology use category. Table 6-8 presents the stakeholder success response rates received for each Task

Automation work function selected for analysis and the results of the variation analysis. Bold, underlined values with arrows indicating direction in Table 6-8 represent those exceeding the boundaries established in Table 6-2.

Table 6-7: TA Work Function Technology Usage Level vs. Stakeholder Success Responses

TA Work Function	Technology Level (Project IA Index)		Stakeholder Success (N)		
			Only Some	Nearly All	All
101	High	>5.7	2	2	8
	Med	2.1 - 5.69	8	19	25
	Low	<2.1	2	4	3
205	High	>5.7	4	7	12
	Med	2.1 - 5.69	13	26	39
	Low	<2.1	2	4	6
206	High	>5.7	2	6	7
	Med	2.1 - 5.69	10	25	27
	Low	<2.1	2	2	4
207	High	>5.7	3	7	12
	Med	2.1 - 5.69	13	27	38
	Low	<2.1	1	4	7
208	High	>5.7	3	7	11
	Med	2.1 - 5.69	13	25	40
	Low	<2.1	2	3	4
209	High	>5.7	3	4	8
	Med	2.1 - 5.69	13	23	37
	Low	<2.1	2	3	4

TA Work Function	Technology Level (Project IA Index)		Stakeholder Success (N)		
			Only Some	Nearly All	All
212	High	>5.7	4	9	13
	Med	2.1 - 5.69	10	28	41
	Low	<2.1	3	5	5
214	High	>5.7	4	8	13
	Med	2.1 - 5.69	12	30	43
	Low	<2.1	2	4	7
306	High	>5.7	4	10	15
	Med	2.1 - 5.69	13	38	57
	Low	<2.1	5	6	11
401	High	>5.7	4	9	15
	Med	2.1 - 5.69	14	40	57
	Low	<2.1	5	6	11
408	High	>5.7	4	8	16
	Med	2.1 - 5.69	13	38	52
	Low	<2.1	6	6	11
602	High	>5.7	1	4	9
	Med	2.1 - 5.69	11	28	41
	Low	<2.1	4	1	6
606	High	>5.7	1	2	9
	Med	2.1 - 5.69	10	24	39
	Low	<2.1	4	2	7

Table 6-8: TA Work Function Technology Usage Level vs. Stakeholder Success Rate

TA Work Function	Technology Level (Project IA Index)		Stakeholder Success (%)		
			Only Some	Nearly All	All
101	High	>5.7	16.67	**↓16.67**	**↑66.67**
	Med	2.1 - 5.69	15.38	36.54	48.08
	Low	<2.1	**↑22.22**	**↑44.44**	**↓33.33**
205	High	>5.7	17.39	30.43	52.17
	Med	2.1 - 5.69	16.67	33.33	50.00
	Low	<2.1	16.67	33.33	50.00
206	High	>5.7	13.33	**↑40.00**	**↓46.67**
	Med	2.1 - 5.69	16.13	**↑40.32**	**↓43.55**
	Low	<2.1	**↑25.00**	25.00	50.00
207	High	>5.7	13.64	31.82	54.55
	Med	2.1 - 5.69	16.67	34.62	48.72
	Low	<2.1	**↓8.33**	33.33	58.33
208	High	>5.7	14.29	33.33	52.38
	Med	2.1 - 5.69	16.67	32.05	51.28
	Low	<2.1	**↑22.22**	33.33	**↓44.44**
209	High	>5.7	20.00	26.67	53.33
	Med	2.1 - 5.69	17.81	31.51	50.68
	Low	<2.1	**↑22.22**	33.33	**↓44.44**
212	High	>5.7	15.38	34.62	50.00
	Med	2.1 - 5.69	12.66	35.44	51.90
	Low	<2.1	**↑23.08**	**↑38.46**	**↓38.46**
214	High	>5.7	16.00	32.00	52.00
	Med	2.1 - 5.69	14.12	35.29	50.59
	Low	<2.1	15.38	30.77	53.85

TA Work Function	Technology Level (Project IA Index)		Stakeholder Success (%)		
			Only Some	Nearly All	All
306	High	>5.7	13.79	34.48	51.72
	Med	2.1 - 5.69	12.04	35.19	52.78
	Low	<2.1	**↑22.73**	27.27	50.00
401	High	>5.7	14.29	32.14	53.57
	Med	2.1 - 5.69	12.61%	36.04	51.35
	Low	<2.1	**↑22.73**	27.27	50.00
408	High	>5.7	14.29	28.57	57.14
	Med	2.1 - 5.69	12.62	36.89	50.49
	Low	<2.1	**↑26.09**	26.09	47.83
602	High	>5.7	**↓7.14**	28.57	**↑64.29**
	Med	2.1 - 5.69	13.75	35.00	51.25
	Low	<2.1	**↑36.36**	**↓9.09**	54.55
606	High	>5.7	**↓8.33**	**↓16.67**	**↑75.00**
	Med	2.1 - 5.69	13.70	32.88	53.42
	Low	<2.1	**↑30.77**	**↓15.38**	53.85

The purpose of this analysis was primarily to determine if the degree of technology used in selected Task Automation functions is associated with the level of stakeholder success achieved. Once a work function technology usage is determined to be strongly associated with stakeholder success, then evaluating the direction of association is prudent. Those Task Automation work functions associated with stakeholder success and the direction of the association are presented in Table 6-9.

Table 6-9: Stakeholder Success-Sensitive TA Work Functions

ID	Description	Stakeholder Success Associated WFs	
		POSITIVE	NEGATIVE
		Increase in All share success & High Tech OR *Decrease* in Only Some share success & Low Tech	*Decrease* in All share success & High Tech OR *Increase* in Only Some share success & Low Tech
101	Conduct market analysis or need	X	X
208	Design the electrical system and related drawings		X
209	Design the HVAC system and related drawings		X
212	Prepare project specifications		X
602	Train facility operators (simulations, software, etc.)	X	X
606	Monitor and assess equipment operations	X	X

Six of the 13 Integration Link work functions analyzed are thought to be related to stakeholder success. Insights into each of these work functions include:

WF 101: Conduct market analysis or need

Identifying a market, estimating its potential and anticipated revenues are just some of the activities involved in market analysis. Market analysis usually involves significant time and money to collect information; therefore, it has substantial impacts on the fiscal success received by the stakeholders. The level of technology used to conduct market analysis has a direct relationship to the stakeholder's success. There is a strong trend for projects that have high technology use in conducting market analysis to experience an increase in stakeholder success while projects using lower technology to assess the market experience a decrease in stakeholder success.

WF 208: Design the electrical system and related drawings

As in work function 206, the design of electrical systems serves to affect historical measures of project success. Similar to work function 206, technology use in this work function is related to overall stakeholder success. Using higher levels of technology is not related to increased stakeholder success but the use of lower technology is tied to decreases in the level of stakeholder success achieved.

WF 209: Design the HVAC system and related drawings

Similar to work function 208, using higher levels of technology is not related to increased stakeholder success but the use of lower technology is linked with a decrease in the stakeholder success level. Perhaps because this work function along with work functions 208 and 212 were the first to benefit from computing through computer aided design type packages, the increased use of technology is the rule rather than an exception. Because this may be today's standard, the absence of efficient use of the technology may cause these results.

WF 212: Prepare project specifications

Project specifications are the key documents in determining the product received by the owner. Failure to accurately communicate the owner's need through the specifications creates numerous problems, change orders, and an additional resource drain. As with the previous work function, using higher levels of technology does not have a relationship with increased stakeholder success but the use of lower technology is associated with a decrease in the stakeholder success level which suggests the importance of accurate specifications is ignored unless a problem develops during execution.

WF 602: Train facility operators (simulations, software, etc.)

The owner or his representatives have vested stake in the proper operation of a facility and its components. Often overlooked in the early stages of a project, the quality and quantity of training for a facility operation is crucial to owner and

stakeholder success. This is strongly reflected in the data as high technology use is strongly related to increases in stakeholder success while low technology use is related to decreases in stakeholder success.

WF 606: Monitor and assess equipment operations

Part of the responsibility of operating a facility is to monitor the performance of critical elements. Based on the results of work function 602, it is no surprise that an increase in technology use is linked to increases in stakeholder success and a decrease in technology use is linked to decreases in stakeholder success.

Chapter 7: Conclusions and Recommendations

7.1 Review of Research Objectives

The purpose of this study was to investigate stakeholder success on capital facility projects and its associations with project characteristics and level of technology usage. Rates of stakeholder success were compared to project characteristic and other project performance variables to determine direction and severity of deviations from the expected stakeholder success rates. Stakeholder success rates were also related to technology usage at the project and work function levels. In attempting to understand the links between technology usage and stakeholder success, work functions commonly associated with other success measures (under budget, on time, improved quality and performance) were identified. Relations were drawn between the level of technology usage and stakeholder success for each selected work function to identify those work functions in which stakeholder success may be leveraged by technology usage.

The primary research objectives are presented as follows:

1) Analyze stakeholder success rates as measured against such project characteristics as size, type of project, industry sector, ownership, and initial site.
2) Analyze stakeholder success rates in comparison with cost and schedule success measures.
3) Analyze relationships between project technology usage and stakeholder success at the project level.

4) Analyze relationships between project technology usage and stakeholder success at the work function level.

7.2 CONCLUSIONS

Project Characteristics Related to Stakeholder Success

An industry-wide survey and analysis of more than 190 capital facility projects was performed in order to quantify whether stakeholder success is associated with project characteristics and project-level technology usage. Data were analyzed using appropriate analysis techniques. The analyses indicate that there are potentially meaningful relationships between stakeholder success and project characteristics.

From the analysis of the associations between stakeholder success and project characteristic variables, the following can be concluded;

- Projects greater than $100 Million in total installed cost experience lower rates of stakeholder success, suggesting that stakeholder success is harder to achieve on high-dollar, more complex projects.
- Either stakeholders are more comfortable with mid-size projects or the construction-project management team is more effective at managing resources and delivering a successful project on mid-size (20 to 50 million TIC) projects.
- The projects with a TIC ranging from 5 to 20 million dollars offer a strong relationship to stakeholder success. Those projects with nearly all stakeholders experiencing success remains at the expected value

while there is a large swing from those projects with all stakeholders experiencing success to projects with only some stakeholders experiencing success. This indicates a tendency for increasing stakeholder dissatisfaction among this industry demographic.

- The industrial building sector reports lower levels of stakeholder success than building or infrastructure construction.
- Surprisingly, the state of the initial site does not have a meaningful relationship with level of stakeholder success. This is a departure from the conventional wisdom that renovation and expansion projects are more difficult and complex and thus harder to achieve stakeholder success when compared to greenfield construction.
- Although small in total number of projects analyzed, stakeholder success is stronger among those projects that incorporate higher levels of technology over the project life cycle than those employing lower levels of technology.
- No consequential distinction can be drawn between public and private projects. This is interesting as public work is often viewed as mismanaged, which should increase the level of frustration amongst stakeholders and thus decrease stakeholder success.
- Survey respondents with greater than ten years of experience are more likely to experience higher levels of stakeholder success. This may be due to their previous exposure to unsuccessful projects and they are more forgiving when assessing current projects.

- In a contrast to information characterized by the operations start date, the respondent's perspective suggests that those in the operations segment of business experienced lower levels of stakeholder success.
- Those in the business unit were inclined to classify a project as successful to all stakeholders more often than those involved with the project management or operations unit.

Project Performance Related to Stakeholder Success

The following can be concluded from analysis of the associations between stakeholder success and project performance variables:

- The cost performance of a project does not have a significant relationship with the level of stakeholder success realized.
- A tradeoff appears to exist between completing a project early and the level of success achieved by the stakeholders. There is a relationship associating lower levels of stakeholder success with those projects completing earlier than planned.
- Unlike project completion, the timing of the operations start, which does affect the "bottom line" of the owner, does not appear to be related to stakeholder success rates.
- Perhaps as expected, those projects with reportable safety mishaps reflect increasing stakeholder *dissatisfaction*.

Project and Work Function Technology Usage Related to Stakeholder Success

In analyzing overall technology usage at the project level as it correlates to stakeholder success, the following is concluded: Lower levels of technology utilization at the project level are associated with lower levels of success experienced by stakeholders.

Analysis of technology usage levels for work functions thought to affect typical success metrics resulted in 15 work functions with strong associations with stakeholder success. The work functions are either positively or negatively associated with stakeholder success.

The work functions that are *positively* associated with stakeholder success are those representing an *increase* in the level of stakeholder success with *higher* technology usage, and include the following:

- WF 605: Develop maintenance plans from maintenance history data
- WF 607: Facility operators request maintenance or modifications
- WF 610: Monitor environmental impact of facility operations

The work functions that are *negatively* associated with stakeholder success are those representing a *decrease* in the level of stakeholder success on those projects with *lower* technology usage, and include the following:

- WF 208: Design the electrical system and related drawings
- WF 209: Design the HVAC system and related drawings
- WF 212: Prepare project specifications

- WF 308: Prepare and submit shop drawings
- WF 402: Track field work progress and labor cost code charges

Many work functions are both positively and negatively associated with stakeholder success, and include the following:

- WF 101: Conduct market analysis or need
- WF 409: Work crews submit & receive answers to Requests for Information
- WF 509: Acquire and record laboratory test information
- WF 602: Train facility operators (simulations, software, etc.)
- WF 604: Track and analyze the maintenance history of important equipment
- WF 606: Monitor and assess equipment operations
- WF 609: Monitor/track/control facility energy usage

7.3 Recommendations

Recommendations for future research are summarized below:

- Study the classifications of stakeholders common to each construction project, particularly owners, constructors, and users to differentiate success motivators beyond cost and schedule for each group.
- Explore the links between stakeholder success and work functions in additional detail. Attempt to eliminate mixed results and

identify work functions as being either positively or negatively leveraging of stakeholder success.

- Where sample sizes are small, collect additional data to evaluate the relationships between stakeholder success to technology usage and project characteristics to enable statistical analysis.

Appendix A. Data Collection Tool for Technology Usage Assessment

Contact Information

Contact Name:		
Phone Number: ( ) -	**Fax Number:** ( ) -	**E-mail Address:**
Contact's Perspective: *which of the categories below best describes your perspective of the project?* ☐ Business Unit (project initiator, investor, senior management) ☐ Project Team (responsible for delivering an operational facility) ☐ Operations (responsible for operation of the completed facility)		
Experience: *how many years of experience have you had in this position?* ☐ <5 ☐ 5-10 ☐ 10-20 ☐ >20		

Company Information

Company Name:
Company Type: ☐ Public Owner ☐ Design-Build or EPC   ☐ Private Owner ☐ Supplier or Fabricator   ☐ Design Consultant or A/E ☐ Subcontractor   ☐ Prime Contractor or GC Other (please describe):______________
Company Size: Owners ($ Annual Capital Budget): ______________   A/E's & Contractors ($ Annual Sales Volume): ______________

Project Information

Project Name: **Project Location:** Domestic ______________ State (U.S.) International ______________ Country	**Project I.D.** *You may use any reference to protect the project's identity. The purpose of this I.D. is to help you and CII/Sloan personnel identify the questionnaire correctly if clarification of data is needed and to prevent duplicate project entries*
Project Completion Date: ________ ☐ actual ☐ projected	
Total Installed Cost: ☐ <$5 Million ☐ $5-20 Million ☐ $20-50 Million ☐ $50-100 Million ☐ >$100 Million	
Project Nature: ☐ "Green Field" ☐ Renovation ☐ Expansion	

Project Information (continued)

Project Type: *of the project types listed below, which best describes your project?*

Industrial	Infrastructure	Buildings
☐ Foods	☐ Water/Wastewater	☐ Single-unit Residential
☐ Pharmaceuticals Mfg.	☐ Electrical Distribution / Communications	☐ Multi-unit Residential (low-rise)
☐ Consumer Products Mfg.	☐ Tunneling	☐ Multi- unit Residential (mid-rise and high-rise)
☐ Automotive	☐ Highway	☐ Hotel / Motel
☐ Microelectronics Mfg.	☐ Airport	☐ Low-rise Office
☐ Pulp and Paper	☐ Rail	☐ Mid-rise Office
☐ Power Generation	☐ Flood Control	☐ High-rise Office
☐ Petroleum Refining	☐ Navigation	☐ Retail
☐ Chemical Mfg.	☐ Marine Facilities	☐ Parking Garage
☐ Oil & Gas Production	☐ Mining	☐ Warehouse
☐ Environmental / Remediation	☐ Solid Waste Management	☐ Educational
☐ Metals Refining/Processing		☐ Hospital / Clinic
		☐ Laboratory
		☐ Correctional
		☐ Entertainment

Other: *(please specify)* ______________________

Cost Performance:

The total installed cost of the project was...
- ☐ Significantly under authorized Budget
- ☐ Essentially the same as Authorized Budget
- ☐ Significantly over Authorized Budget

After 4-6 months of operations, the operating cost of the facility was . . .
- ☐ A problem
- ☐ Not a problem
- ☐ Don't know

Schedule Performance:

The actual project completion date was...
- ☐ Significantly earlier than planned
- ☐ Essentially the same as the planned
- ☐ Significantly later than planned

The actual operations start date was...
- ☐ Significantly earlier than planned at authorization
- ☐ Essentially at the planned start date
- ☐ Significantly later than planned at authorization

Safety: *were there any OSHA reportable injuries during the project?*
- ☐ Yes
- ☐ No
- ☐ Don't know

Stakeholder Success: *e.g. owner, A/E, contractor, etc.*
- ☐ All project stakeholders shared in project success
- ☐ Nearly all project stakeholders shared in project success
- ☐ Only some project stakeholders shared in project success

Can a significant portion of the project outcome be credited to (or blamed on) the use of technology? ☐ Yes ☐ No

How does the degree of technology use on this project compare with other projects your company has participated in?

☐ Typical ☐ Advanced

Part 1. Front End

Degree of Technology Use	Level 1	Level 2	Level 3
Characteristics	No electronic tools -or- Commonly-used electronic tools	Specialized, stand-alone electronic tools	Integrated electronic tools
	Hand written data	Data in electronic format	Shared electronic data (e.g. network)
	Verbal or paper data transfer / little or no re-use of data	Electronic data entered numerous times	Single entry of data / re-cycling of data
	Human to human		Machine to machine
	Proximity important to information transfer		Proximity is irrelevant
Example: Needs Analysis	Traffic counting machines gather data, which is collected periodically and stored in paper files.	Traffic data is stored in a stand-alone GIS database, which is updated periodically.	GIS database linked to citywide sensor network displays real-time traffic data and trends.

ID	Task	Degree of Technology Use					Comments
		Don't Know	1	2	3	N/A	
1.01	Conduct market analysis or need analysis for a new facility	☐	☐	☐	☐	☐	
1.02	Develop, evaluate, and refine the project's scope of work	☐	☐	☐	☐	☐	
1.03	Diagram the manufacturing process -or- the user's processes ("bubble diagram")	☐	☐	☐	☐	☐	
1.04	Estimate a budget from the scope of work	☐	☐	☐	☐	☐	
1.05	Develop a milestone schedule from the scope of work	☐	☐	☐	☐	☐	
1.06	Acquire and store site investigation data for use during design	☐	☐	☐	☐	☐	

1.07 Describe the most <u>beneficial</u> technologies used in *front-end* processes at your company:

Part 2. Design

Degree of Technology Use	Level 1	Level 2	Level 3
Characteristics	No electronic tools -or- Commonly-used electronic tools	Specialized, stand-alone electronic tools	Integrated electronic tools
	Hand written data	Data in electronic format	Shared electronic data (e.g. network)
	Verbal or paper data transfer / little or no re-use of data	Electronic data entered numerous times	Single entry of data / re-cycling of data
	Human to human		Machine to machine
	Proximity important to information transfer		Proximity is irrelevant
Example: Design Structural System	Designer gets loads from a manual; puts a concept on paper; passes to a draftsman who draws by hand. Details are cut and pasted on drawings.	Designer gets loads from stand-alone software; puts a concept on CAD and gives the disk to a CAD technician for details	Designers from all disciplines collaborate on a network with a common CAD model. Details automatically added from database

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	Comments
2.01	Designers access supplier information in order to select components	☐	☐	☐	☐	☐	
2.02	Get input from operators and builders regarding construction methods selection, & construction sequencing	☐	☐	☐	☐	☐	
2.03	Analyze alternative construction methods for effects on cost, schedule, etc.	☐	☐	☐	☐	☐	
2.04	Use conceptual design work as a basis for detailed design work	☐	☐	☐	☐	☐	
2.05	Generate facility floor plans	☐	☐	☐	☐	☐	
2.06	Design the fluid transport system (open channel or pipes) and related drawings	☐	☐	☐	☐	☐	
2.07	Design the structural system and related drawings	☐	☐	☐	☐	☐	
2.08	Design the electrical system and related drawings	☐	☐	☐	☐	☐	
2.09	Design the HVAC system and prepare related drawings	☐	☐	☐	☐	☐	
2.10	Document the assumptions used in developing the budget, and pass to the next phase	☐	☐	☐	☐	☐	
2.11	Detect physical interference between systems (i.e. plumbing, electrical, structural, etc.)	☐	☐	☐	☐	☐	
2.12	Prepare project specifications	☐	☐	☐	☐	☐	
2.13	Check the design against owner requirements (e.g. design reviews) and code requirements	☐	☐	☐	☐	☐	
2.14	Track design progress	☐	☐	☐	☐	☐	

2.15 Describe the most beneficial technologies used during *detailed design* at your company:

Part 3. Procurement

Degree of Technology Use	Level 1	Level 2	Level 3
Characteristics	No electronic tools -or- Commonly-used electronic tools	Specialized, stand-alone electronic tools	Integrated electronic tools
	Hand written data	Data in electronic format	Shared electronic data (e.g. network)
	Verbal or paper data transfer / little or no re-use of data	Electronic data entered numerous times	Single entry of data / re-cycling of data
	Human to human		Machine to machine
	Proximity important to information transfer		Proximity is irrelevant
Example: Bid Proposal	• Get paper copies of drawings/specs • Input the prices in a spreadsheet • Hand a hard copy of proposal to owner	• Get CD-ROM files of CAD model • Compile bid with special software • Give owner a disk copy of proposal	• Download CAD files from network • Obtain bids from subs electronically • Transmit file via network to owner

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	Comments
3.01	Determine the lead time required to order equipment and materials	☐	☐	☐	☐	☐	
3.02	Conduct a quantity survey of drawings	☐	☐	☐	☐	☐	
3.03	Link quantity survey data to the cost estimating process	☐	☐	☐	☐	☐	
3.04	Link supplier cost quotes to the cost estimating process	☐	☐	☐	☐	☐	
3.05	Refine the preliminary budget estimate	☐	☐	☐	☐	☐	
3.06	Develop the milestone schedule	☐	☐	☐	☐	☐	
3.07	Develop and transmit requests for proposal to suppliers and subs	☐	☐	☐	☐	☐	
3.08	Prepare & submit shop drawings	☐	☐	☐	☐	☐	
3.09	Acquire & review shop drawings; send response	☐	☐	☐	☐	☐	
3.10	Compile quotes from suppliers & subs into a bid or proposal package	☐	☐	☐	☐	☐	
3.11	Monitor the progress of fabricators	☐	☐	☐	☐	☐	
3.12	Plan the transportation routes of large items from the fabricator to the job site	☐	☐	☐	☐	☐	

3.13 Describe the most <u>beneficial</u> technologies used during *procurement* at your company:

Part 4. Construction Management

Degree of Technology Use	Level 1	Level 2	Level 3
Characteristics	No electronic tools -or- Commonly-used electronic tools	Specialized, stand-alone electronic tools	Integrated electronic tools
	Hand written data	Data in electronic format	Shared electronic data (e.g. network)
	Verbal or paper data transfer / little or no re-use of data	Electronic data entered numerous times	Single entry of data / re-cyclir of data
	Human to human		Machine to machine
	Proximity important to information transfer		Proximity is irrelevant
Example: Cost Estimate	• Unit prices from a book • Paper & pencil quantity survey	• Prices from stand-alone database • Special software performs quantity survey on digitized drawings	• Estimating software linked electronically to CAD-based quantity survey & supplier prices
	• Data manually entered into spreadsheet	• Enter data into estimating software	• Data automatically entered

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	Comments
4.01	Develop the construction schedule	☐	☐	☐	☐	☐	
4.02	Track field work progress & labor cost code charges	☐	☐	☐	☐	☐	
4.03	Maintain a daily job diary	☐	☐	☐	☐	☐	
4.04	Update the current cost forecast	☐	☐	☐	☐	☐	
4.05	Keep all project team members up to date on construction progress	☐	☐	☐	☐	☐	
4.06	Track the inventory of materials on site	☐	☐	☐	☐	☐	
4.07	Link field material managers to suppliers	☐	☐	☐	☐	☐	
4.08	Develop short-term work schedules based on labor, equipment, and material availability	☐	☐	☐	☐	☐	
4.09	Work crews submit and receive answers to Requests for Information (RFI's)	☐	☐	☐	☐	☐	
4.10	Builders provide feedback about the effects of design changes, made by owner or A/E, on cost and schedule	☐	☐	☐	☐	☐	
4.11	Communicate design changes to field personnel	☐	☐	☐	☐	☐	
4.12	Communicate status of change orders to field	☐	☐	☐	☐	☐	
4.13	Update as-built drawings	☐	☐	☐	☐	☐	
4.14	Contractors submit requests for payment	☐	☐	☐	☐	☐	
4.15	Transfer funds from owner's account to contractor	☐	☐	☐	☐	☐	

4.16 Describe the most <u>beneficial</u> technologies used in *managing construction projects* at your company:

Part 5. Construction Execution

Degree of Technology Use	Level 1	Level 2	Level 3
Characteristics	Labor intensive, little mechanization Human Laborer	Some mechanization Machine assists human Operator	Mechanization linked with external information Human assists machine Technician
Example: Hang sheet rock Site preparation	• Manual placement • Shovel	• Human guides machine to lift it into place • Grader	• Machine linked to CAD model cuts and hangs with minimal assistance • Grader linked to GPS

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	Comments
5.01	Evaluate subsurface conditions	☐	☐	☐	☐	☐	
5.02	Carry out earthwork and grading	☐	☐	☐	☐	☐	
5.03	Construct rebar cages	☐	☐	☐	☐	☐	
5.04	Weld pipes	☐	☐	☐	☐	☐	
5.05	Select the appropriate crane for heavy lifts	☐	☐	☐	☐	☐	
5.06	Provide an elevated work platform	☐	☐	☐	☐	☐	
5.07	Fabricate roof trusses	☐	☐	☐	☐	☐	
5.08	Manipulate and hang sheet rock	☐	☐	☐	☐	☐	
5.09	Acquire & record laboratory test information	☐	☐	☐	☐	☐	
5.10	Finish concrete surfaces	☐	☐	☐	☐	☐	
5.11	Apply paint or coatings	☐	☐	☐	☐	☐	

5.12 Describe the most <u>beneficial</u> technologies used in executing construction projects at your company:

Part 6. Start-up, Operations & Maintenance

Degree of Technology Use	Level 1	Level 2	Level 3
Characteristics	No electronic tools -or- Commonly-used electronic tools	Specialized, stand-alone electronic tools	Integrated electronic tools
	Hand written data	Data in electronic format	Shared electronic data (e.g. network)
	Verbal or paper data transfer / little or no re-use of data	Electronic data entered numerous times	Single entry of data / re-cyclin of data
	Human to human		Machine to machine
	Proximity important to information transfer		Proximity is irrelevant
Example: Maintenance Plan	• Maintenance history in paper files	• Maintenance history in database	• Database from the job site
	• Manufacturer data in paper files	• Manufacturer data on disks	• Manufacturer's data from a web sit
	• Plan written on word processor	• Plan kept in stand-alone database	• Database linked to all operators

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	Comments
6.01	Conduct pre-operations testing	☐	☐	☐	☐	☐	
6.02	Train facility operators (e.g. simulations, software)	☐	☐	☐	☐	☐	
6.03	Use as-built information in personnel training	☐	☐	☐	☐	☐	
6.04	Track & analyze the maintenance history of important equipment	☐	☐	☐	☐	☐	
6.05	Develop maintenance plans from maintenance history data	☐	☐	☐	☐	☐	
6.06	Monitor & assess equipment operations	☐	☐	☐	☐	☐	
6.07	Facility operators request maintenance or modifications	☐	☐	☐	☐	☐	
6.08	Update as-built drawings in response to facility modifications	☐	☐	☐	☐	☐	
6.09	Monitor/track/control facility energy usage	☐	☐	☐	☐	☐	
6.10	Monitor environmental impact of facility operations (e.g. air / water quality)	☐	☐	☐	☐	☐	

6.11 Describe the most beneficial technologies used in facility startup, operations, and maintenance at your company

Appendix B. List of Automation Tasks and Integration Links

Question ID	Description	Classification	
		Task	Integration Link
101	Conduct market analysis or need analysis for a new facility	X	
102	Develop, evaluate, and refine the project's scope of work	X	
103	Diagram the manufacturing process –or- the user's processes ("bubble diagram")	X	
104	Estimate a budget from the scope of work		X
105	Develop a milestone schedule from the scope of work		X
106	Acquire and store site investigation data for use during design		X
201	Designers access supplier information in order to select components		X
202	Get input from operators and builders regarding construction methods selection, & construction sequencing		X
203	Analyze alternative construction methods for effects on cost, schedule, etc.		X
204	Use conceptual design work as a basis for detailed design work		X
205	Generate facility floor plans	X	
206	Design fluid transport system (open channel or pipes) and related drawings	X	
207	Design the structural system and related drawings	X	
208	Design the electrical system and related drawings	X	
209	Design the HVAC system and prepare related drawings	X	
210	Document the assumptions used in developing the budget, and pass to the next phase		X

Question ID	Description	Classification	
		Task	Integration Link
211	Detect physical interference between systems (i.e. plumbing, electrical, structural, etc.)		X
212	Prepare project specifications	X	
213	Check the design against owner requirements (e.g. design reviews) and code requirements		X
214	Track design progress	X	
301	Determine the lead time required to order equipment and materials		X
302	Conduct a quantity survey of drawings	X	
303	Link quantity survey data to the cost estimating process		X
304	Link supplier cost quotes to the cost estimating process		X
305	Refine the preliminary budget estimate	X	
306	Develop the milestone schedule	X	
307	Develop and transmit requests for proposal to suppliers and subs		X
308	Prepare & submit shop drawings		X
309	Acquire & review shop drawings; send response		X
310	Compile quotes from suppliers & subs into a bid or proposal package		X
311	Monitor the progress of fabricators		X
312	Plan the transportation routes of large items from the fabricator to the job site	X	
401	Develop the construction schedule	X	
402	Track field work progress & labor cost code charges		X
403	Maintain a daily job diary	X	
404	Update the current cost forecast	X	
405	Keep all project team members up to date on construction progress		X
406	Track the inventory of materials on site		X
407	Link field material managers to suppliers		X

Question ID	Description	Classification	
		Task	Integration Link
408	Develop short-term work schedules based on labor, equipment, and material availability	X	
409	Work crews submit and receive answers to Requests for Information (RFI's)		X
410	Builders provide feedback about the effects of design changes, made by owner or A/E, on cost and schedule		X
411	Communicate design changes to field personnel		X
412	Communicate status of change orders to field		X
413	Update as-built drawings		X
414	Contractors submit requests for payment		X
415	Transfer funds from owner's account to contractor		X
501	Evaluate subsurface conditions	X	
502	Carry out earthwork and grading	X	
503	Construct rebar cages	X	
504	Weld pipes	X	
505	Select the appropriate crane for heavy lifts	X	
506	Provide an elevated work platform	X	
507	Fabricate roof trusses	X	
508	Manipulate and hang sheet rock	X	
509	Acquire & record laboratory test information		X
510	Finish concrete surfaces	X	
511	Apply paint or coatings	X	
601	Conduct pre-operations testing	X	
602	Train facility operators (e.g. simulations, software)	X	
603	Use as-built information in personnel training		X
604	Track & analyze the maintenance history of important equipment		X
605	Develop maintenance plans from maintenance history data		X

Question ID	Description	Classification	
		Task	Integration Link
606	Monitor & assess equipment operations	X	
607	Facility operators request maintenance or modifications		X
608	Update as-built drawings in response to facility modifications		X
609	Monitor/track/control facility energy usage		X
610	Monitor environmental impact of facility operations (e.g. air/water quality)		X

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Vita

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